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Comparison of Soil Classification Methods Using CPT Results

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ABSTRACT:

A series of cone penetration test were conducted in the southeast of Tehran to assess the liquefaction potential in this area. At the same time, after sounding of each cone penetration test, soil samples were also taken from different depths of boreholes to visually verify the soil classification. Seventy four samples from twenty boreholes were taken and their soil characteristics were obtained. To classify the soil layers, using recorded data, two various soil behaviour classification charts proposed by Robertson and Wride (1988), and Marr (1981) were examined which for some cases different results were obtained. In this paper validity of these procedures are investigated and discussed in details. These soil classification methods in some cases give a good results but there is a different between those charts and observed soil classification, particularly when the soil contain fines and therefore some modification must be applied.

INTERODUCTION

One of the advantages of using CPT as a in-situ test is that a continuous profile of penetration resistance is developed for stratigraphic interpretation. A primary purpose of the CPT is to identify the soil layer boundaries and determine soil type , i.e soil profilling. Since the soil sample is not retrived with cone penetration test, in recent years various soil classification methods have been proposed by some researches in which charts have been plotted based on cone penetration test data such as cone resistance (q_c), sleeve friction (f_s) and Pore pressure(u) (Begman (1965),Robertsonet al.,(1986), Robertson (1990), Olsen (1998) ,Robertson and Wride (1998)).

Although these charts have been commonly used by Geotechnical engineers, new questions have recently been raised about their validity specially when fine soils are involved. For instance, in Robertson's method which is one of the most recent CPT-based chart, there are serious questions regarding validity of Ic.Therefore, in this research credibility of Robertson's method is investigated and furthermore, since the Marr's method is an earlier methods in which f_s and q_c is directly used, to compare with the observed classification, this method is also investigated.

PROJECT DESCRIPTION

In this project, twenty cone penetration tests were performed to assess liquefaction potential of southeast of Tehran. Also, seventy four samples were taken to evaluate validity of some soil classification methods.

The site of project is located at an urban area in soultheast of Tehran. For this reasone, to select the location of boreholes, it was necessary to study the region carefully and to find the sites which soundings were feasible considering the traffic and private property problems. With those cautions, appropriate locations for testing and sampling were selected. Figure (1) shows the map of borholes in southeast of Tehran .

To perform the cone penetration tests and sampling, the100 kN capacity cone penetration system , of Iran University of Science and Technology was used. To obtain the soil samples

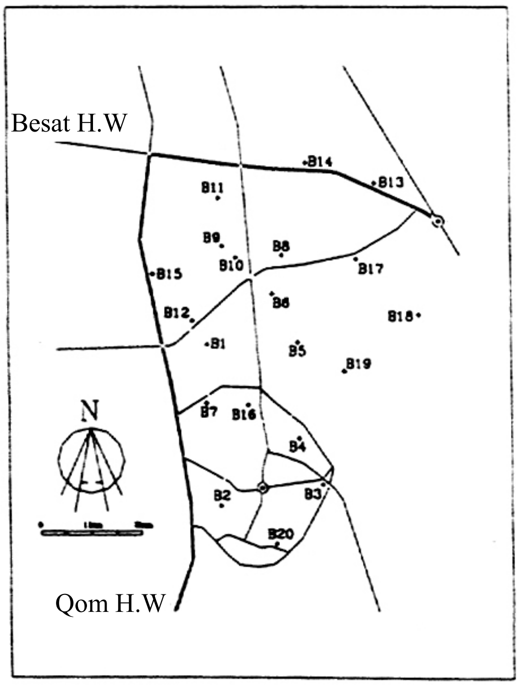


Fig 1. Studied region and location of boreholes

double-tube sampler, mounted on sounding tubes, was also used.

To obtain objectives of project, after seting up the equipment on each specific site, sounding up to 20 meters depth was performed and q_c and f_c were recorded. In Fig (2) results of cone penetration test on borhole No. 9 are shown. After each sounding, samples were taken from different depths of the same site nearly beside the borhole. Then, the top and bottum of tube sample was immediately closed and transported to the soil mechanics laboratory, and soil charactristics tests for each sample was performed. In Table (1) soil charactristics of sample retrived from borhole No. 5 is shown as an example of the soil characteristic. To classify the soil samples, unified soil classification method have been used.

Tab 1: Results of soil identification (B5)

Depth	Fine Con.	LL	PL	Soil Type
2	58	45.1	34.1	ML
3	78	38.3	26.2	ML
4	81	41.3	22.5	CL
8	70	40.2	20.2	CL
12	73	43.3	30.2	ML
18	83	38.2	22	CL

It shoud be mentioned that the ground water level in this site was about 20 meters of surface at the time of testing.

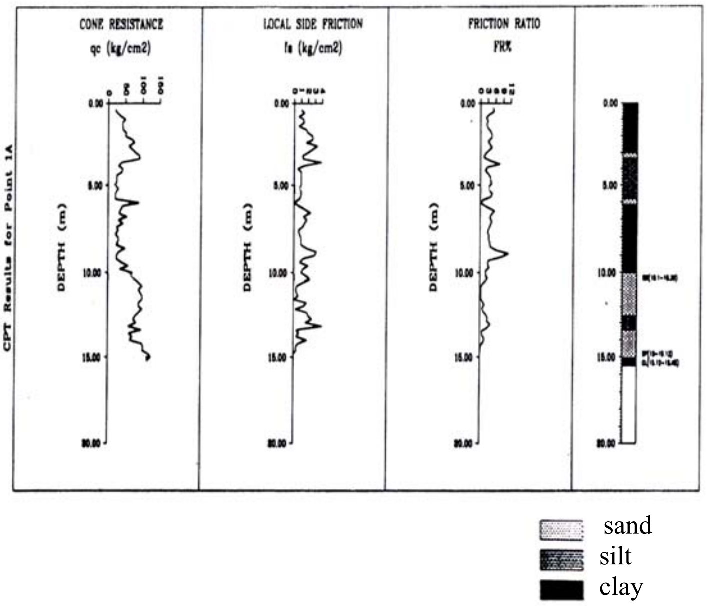


Fig 2.Typical CPT Profile (Borhole No. 9)

CPT - BASED SOIL CLASSIFICATION METHODS

In this research using CPT results and soil sampling, two soil classification methods proposed by Robertson (1998) and Marr (1981) are evaluated. Robertson have proposed a chart using normalized cone resistance (Q) and normalized friction ratio (F) to classify the soil, Fig (3). Recomended equations for computing these parameters are:

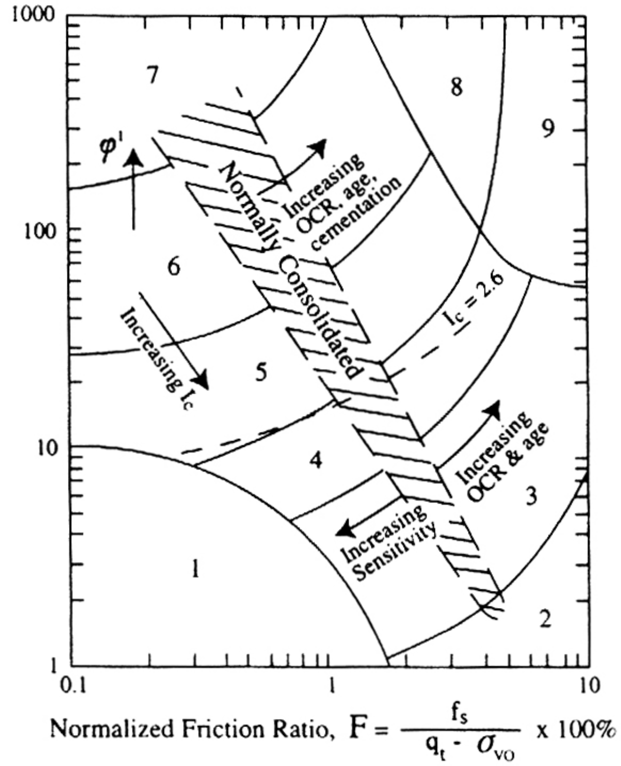
$$Q = \left[\frac{\left(q_c - \sigma_{v_o}\right)}{P_a}\right]\left[\left(\frac{P_a}{\sigma'_{v_o}}\right)^n\right] \tag{1}$$

$$F = \left[\frac{f_s}{\left(q_c - \sigma_{v_o}\right)}\right] \times 100\% \tag{2}$$

where n is an exponent that varies with soil type, and σ_{v_o}, σ'_{v_o} are the total and the effective overburden stresses respectively, P_a is a reference pressure with the same units as overburden stresses,q_c and f_s are cone resistance and sleeve friction respectively.

Based on this method, the boundaries between soil types 2-7 can be approximated by concentric circles. Radius of these circles, termed the soil behavior type index, I_c, is computed from the following equation :

$$I_c=[93.47-\log Q)^2 + (1.22+ \log F)^2]^{0.5} \tag{3}$$



1.Sensitive,fine grained
2.Organic soils – peats
3. Clays- silty clay to clad
4. Silt mixture – clayey silt to silty clay
5. Sand mixture – silty sand to sandy silt
6. Sands – clean sand to silty sand
7. Gravelly sand to dense sand
8. Very stiff sand to clayey sand
9. Very stiff, fine grained*

*Heavily overconsolidated or cemented

Fig.3. CPT –Based Soil Behavior- Type Proposed by Robertson (1990)

In Eq(3), recommended values of (n) in clayey soils is equal to 1, and for clean sands is equal to 0.5. For silts and sandy silts a value intermendiate between 1 and 0.5 would be appropriate. Also, to calculate the soil behavior type index, I_c, the first step is to assume an exponent n of 1.0 and to calculate the dimensionless CPT tip resistance Q from equation (1).

If the I_c calculated with an exponent of 1.0 is greater than 2.6, the soil is classified as clayey soil and if I_c is less than 2.6, the soil is likely granular, and therefore normalized cone resistance Q sould be recalculated using an exponent of n equal to 0.5 and I_c should then be recalculated using Eq(3). If the recalculated I_c is less than 2.6, the soil is classed as nonplastic and granular soil. However, if the recalculated I_c is greater than 2.6, the soil is likely to be very silty and possibly plastic. In this instance, I_c should be recalculated from Eq (3) using n=0.7.

Marr's method (1981) is one of the earlier methods to estimate soil type in which, the value of cone resistances and sleeve friction are directly used. In this procedure, a chart has been constructed using q_c and f_s in which some striaght lines separate six zone of varios soil classification, Fig (4).

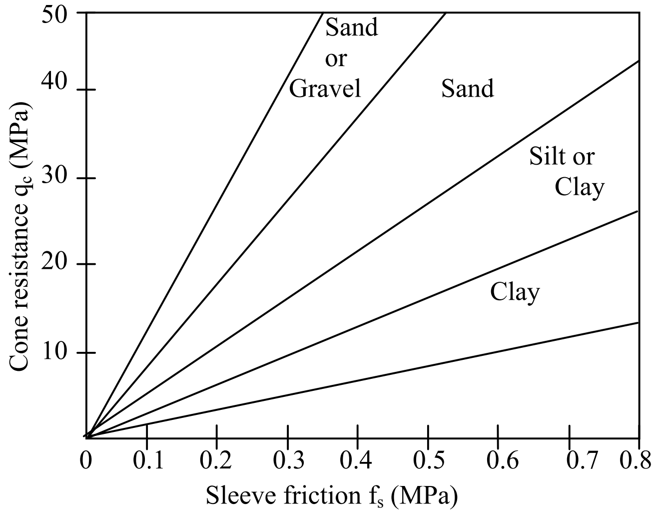


Fig.4. CPT based soil classification chart proposed by Marr (1981)

Based on this chart, If FR<2%, the soil is classified as sands, if 2<FR<4 silt or clay and if FR>4% is classified as clayey soil.

RESULTS AND ANALYSIS

Visual soil classification obtained from retrieved samples and soil classification charts proposed by Robertson and Marr are summaraized In Table (2).

Table 2. Results of soil classification methods

Borhole	Depth (m)	Soil type		
		Lab.	Robertson	Marr
1	2.5	SC-SM	Clay	Clay
1	5.5	ML	Sand Mix	Clay or silt
1	10.5	CL	Sand Mix	Clay or silt
1	15.5	CL	Clay	Clay or silt
2	1	CL	Sand Mix	Clay
2	6.5	CL	Sand Mix	Clay
2	12.8	CL	Clay	Clay
2	17	SC	Clay	Clay or silt
2	18.5	SC	Clay	Clay or silt
2	19.5	SC	Sand	Clay
2	20	SC	Clay	Clay or silt
3	1	Clorol	Sand Mix	Clay
3	2	SC-SM	Sand	Sand
3	3	SC-SM	Sand	Sand
3	4.2	SC-SM	Sand Mix	Sand
3	5	SC-SM	Sand Mix	Sand
3	6	CL	Sand Mix	Sand
3	7	CL	Sand Mix	Sand
3	8	CL	Sand Mix	Clay or silt
3	10	CL	Sand Mix	Clay

Table 2. continue

Borhole	Depth (m)	Soil type		
		Lab.	Robertson	Marr
3	12	CL	Sand Mix	Clay
3	14	CL	Sand Mix	Clay or silt
4	1	OL	Sand Mix	Clay or silt
4	2	OL	Sand Mix	Clay or silt
4	3	SC-SM	Sand	Clay or silt
4	4	SC-SM	Sand	Sand
4	5	SC-SM	Sand	Sand
4	6.8	SC-SM	Sand	Sand
5	2	ML	Sand Mix	Sand
5	3	ML	Sand Mix	Clay or silt
5	4	CL	Sand Mix	Clay or silt
5	8	CL	Sand Mix	Clay
5	12	ML	Sand Mix	Clay
5	14	CL	Sand Mix	Clay or silt
6	1	ML	Sand	Sand
6	2	ML	Sand	Clay or silt
6	4	ML	Sand	Clay or silt
6	6	SC-SM	Sand	Clay or silt
6	7	CL	Sand Mix	Clay
6	10	CL	CL	Clay
6	14	CL	CL	Clay
6	16	CL	Sand Mix	Clay or silt
7	1	CL	Sand Mix	Clay or silt
7	2.5	CL	Sand Mix	Clay
7	4	CL	Sand Mix	Clay or silt
7	5	CL	Sand Mix	Clay
8	1	SC-SM	Sand Mix	Clay
8	2	ML	Sand	sand
8	5	CL	Sand Mix	Clay
8	8	CL	Sand Mix	Clay or silt
8	9.5	SC-SM	Sand Mix	Clay or silt
8	12	ML	Clay	Clay
8	13.5	ML	Clay	Clay
8	15	CL	Sand Mix	Clay
9	10	SC	Sand Mix	Clay or silt
9	15	SW	Sand	Sand
11	5.5	ML	Sand Mix	Clay
12	5.5	ML	Sand Mix	Clay
12	10	MH	Sand Mix	Clay Clay
12	15	ML	Clay	Clay
13	5	SP	Sand Mix	Clay or silt
13	6	SW-SC	Sand Mix	Sand
14	4	ML	Sand Mix	Clay or silt
14	7	SW	Sand	Sand
14	11	ML	Sand	Sand
15	2	CL	Sand	Clay or silt
16	4	ML	Sand Mix	Clay or silt
16	7	CL	Sand Mix	Clay or silt
16	11	SW-SC	Sand Mix	Sand
17	3.5	CL	Sand Mix	Sand
17	10	CL	Sand Mix	Clay or silt
18	4	CL	Sand Mix	Sand
20	5	ML	Sand Mix	Clay or silt
20	9	ML	Sand Mix	Clay or silt

Based on laboratory test results on samples, the number of samples identified as sandy or sandmixture soil, silty soil and clayey soil are equal to 22, 19 and 31, respectively. As shown in this Table, using Robertson's method, from 22 sandy and sand mixture samples, a number of 18, from 19 silty samples, a number of 5 and from 30 clayey soil samples a number of 4 samples are correctly identified. This means that using this method for the area tested in this study, the granular soil with low fines content, can be correctly predicted (about 92%). However, in fine grain soil only about 49% of samples are correctly classified by Robertson's method .

Table (2) also shows, using chart proposed by Marr, results will be different in comparison with previos method. In this case, from 22 sandy soil samples, a number of 10 samples (about 49%) and from 48 fine grain soil sample, a number of 44 samples (about 92%) are correctly determined.

CONCLUSION

Two CPT-based estimation of soil classification and about seventy five soil sampling were studied. Based on obtaind results the following coclusions can be drawn :

- Robertson's method in granular soils for the most cases can identify the soil type correctly.
- Marr's method for the fine grain soils has a good agreement with experimental results.
- It is shown that , using two various charts give different results. Therefore, caution must be taken in applying different proposed charts and in order to verify the soil type in important projects , the soil samples should be taken and tested in the laboratory .

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